INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR
Mid-Spring Semester 2017-18

Date of Examination : 26th April 2019 Session (FN/AN) FN
Duration: 3 hrs Total Points: 100 Department: E & ECE
Subject No. : EC21006 Subject Name : Electromagnetic Engineering

INSTRUCTIONS: Answer **all** the questions. Answer all parts of a question in the **same** place. Start each question from a **new** page. Make appropriate **assumptions** wherever necessary.

1. An electrically small time-varying current element is oriented along z-direction. Derive the expressions for the far-zone Electric and Magnetic fields.

[15 points]

2. Derive the expressions for the electric and magnetic field for the TEM and TE_m mode for an infinite perfectly electric conducting metallic parallel plate with separation distance 'd'. Find the cut-off frequency, the propagation constant and the group velocity.

[15 points]

3. Calculate the propagation and the attenuation constant, and the phase difference between the electric and the magnetic fields for free-space wave propagation in a lossy dielectric medium expressed in the form of complex dielectric constant. Derive the Poynting's theorem for the above case (in phasor notation).

[20 points]

4. Derive the concept of bound surface and volume current densities for a magnetized material. Explain mathematically how you would utilize the concept to calculate the magnetostatic field due to a cylindrical bar magnet of radius 'a' and length 'l'.

[20 points]

5. For a rectangular metallic waveguide of dimension 1.5cm by 2.5cm, filled with material of relative permittivity 4.0 and loss tangent of 0.005, and made of steel of conductivity 1.5 X 10^6 S/m. Derive the cut-off frequency for the dominant mode and the bandwidth of operation. At the center frequency of operation, derive the necessary expressions and calculate the power loss (in dB relative to the input power) in the waveguide over a length 30 cm.

[30 points]

Useful Formula:-

$$\text{div}\,\mathbf{A} = \frac{1}{r^2}\frac{\partial(r^2 A_r)}{\partial r} + \frac{1}{r\sin\theta}\frac{\partial(A_\theta \sin\theta)}{\partial\theta} + \frac{1}{r\sin\theta}\frac{\partial A_\phi}{\partial\phi}$$

$$\text{curl}\,\mathbf{A} = \frac{1}{r\sin\theta}\left(\frac{\partial(A_\phi\sin\theta)}{\partial\theta} - \frac{\partial A_\theta}{\partial\phi}\right)\hat{r} + \frac{1}{r}\left(\frac{1}{\sin\theta}\frac{\partial A_r}{\partial\phi} - \frac{\partial(rA_\phi)}{\partial r}\right)\hat{\theta} + \frac{1}{r}\left(\frac{\partial(rA_\theta)}{\partial r} - \frac{\partial A_r}{\partial\theta}\right)\hat{\phi}$$